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THE LODGEPOLE PINE NEEDLEMINER, RECURVARIA MILLERI BUSK.
LIFE HISTORY AND CONTROL STUDIES IN YOSEMITE NATIONAL PARK, CALIFORNIA
SEASON OF 1937

by
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T A B L E   O F   C O N T E N T S

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INTRODUCTION

The fact that needleminer infestations have at one time or another covered some 30,000 acres within the Park, coupled with the persistent aggressive extension of present centers in the vicinity of Tuolumne Meadows and along the Tioga road, has caused alarm among Park officials. It is feared that continued spread of the insect will result in many additional "ghost forests" of unsightly dead, bleached snags in an area which will be subject to even more intensive recreational use upon the completion of the new Tioga road.

The ultimate purpose of this and previous studies (3 to 9)* has been to cooperate with the National Park Service in finding some means of protecting these aesthetically valuable stands of lodgepole pine in camp ground and road side areas. Moreover, the results of past investigations have indicated that an efficient means of protection may be entirely possible. The most important consideration is the fact that each generation of needleminer requires two years for development; thus if the early stages can be successfully treated, the trees will be free from attack for at least two years. Secondly, although the older larvae and pupae are well protected within the needles, the eggs and newly hatched larvae are exposed and should be more vulnerable. Another favorable point is the stationary habit of the larvae; there is very little if any migration from tree to tree and a tree which is protected in one flight year is free from attack for two years even though there are heavily infested trees in the immediate vicinity. Last, the type of insecticides which will probably be most toxic for eggs and small larvae are relatively inexpensive in cost and application.

The immediate objectivesof the present work were (1) to learn as much as possible of the life history and habits of the insect, and (2) as our information on the biological phases increases, to develop more effective methods of control.

ORGANIZATION AND LOCATION OF WORK

At the beginning of the field season it was intended to carry on life history and control work at the field station at Eight-Mile (Fig. 1,-1), spray tolerance tests at Pot Hole (Fig. 1, -2), and life history and control work at Porcupine Flat (Fig. 1, -3). A change of plans was made later in the season because of the sudden disappearance of the old infestation at Porcupine Flat. This necessitated transfer of part of the work to Forsyth Pass and Forsyth Basin (Fig. 1, 4 and 5).

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* Refers to literature listed on the last page.

Field Station. Eight-Mile. (Elevation 5500 feet)

Because of convenience of equipment and supplies, it was desirable to conduct most of the activities at or near this base. Since the needleminer is not present in the south side of the Park, instead of attempting to work with controlled introductions of adults in the lodgepole pine stands with the attendant risk of moths escaping, small lodgepole pines were transplanted to the field station, a safe distance from the lodgepole pine belt. Fifteen of these small trees, 2 to 2½ feet high, were boxed and moved in the spring as soon as weather permitted. They were placed so as to receive direct sunlight a good part of the day and with frequent watering were soon growing rapidly (Fig. 9). Five of the trees were used for life history studies and four of these were enclosed in small muslin observation cages (Fig. 10); the fifth was placed in a larger cage, 6 x 6 x 6 feet (Fig. 12),, to determine whether the greater space for movement would have any effect on mating and oviposition. The remaining ten trees, used for control tests, were enclosed in small cages of cheesecloth on lath frames. All the trees were set on racks (Fig. 11) to prevent ant invasions.

The trees were to have been infested by liberating known numbers of moths in each cage, but it was found later that the mature larvae and pupae collected at Porcupine Flat were so heavily parasitized that the number of adults emerging was only a fraction of that required. This shortage nearly terminated the work before it was well started, but fortunately the brood in the Forsyth infestation had not emerged and more material was secured from there on July 16 and 23. Because the liberation of known numbers of moths into each cagerequired so much time and handling, that method was abandoned for all but one cage; and instead, the infested needles containing the pupae were placed directly in the cages. A portion of the needles was kept in an emergence box to secure adults for determining sex ratios and incidence of parasitism.

Pot Hole. (Elevation 7800 feet)

The peculiar delayed type of spray burn encountered by Salman (7) made it desirable to add to our meagre information on the reaction of lodgepole pine to different spray materials. In order to have trees of larger size than those at the field station which could be observed during the winter and early spring, a spray plot was established at Pot Hole. A group of 15 trees, 8 to 15 feet high,.located on an open granite sand flat, were selected; these were as nearly representative of the trees sprayed at Porcupine Flat and Forsyth Basin as possible. The spray applications included most of the formulae used in the control tests as well as others. As there is no infestation present, there is no danger of confusing insect injury with any spray injury which may appear.

Porcupine Flat. (Elevation 7900 feet)

Since climatic conditions at the Eight-Mile station are somewhat different from those found in the lodgepole pine type, it was desirable

to have supplementary observations from this area in which a natural infestation had been present for several years.

For ease of observation, small trees rather than larger ones were selected. A group of 12 trees, 8 to 12 feet in height, growing on an open granite sand flat were chosen. As soon as weather permitted (June 30 to July 3), the trees were enclosed in cheesecloth cages 9 x 4 x 4 feet (Fig. 14); where necessary, tops were cut back to make the tree fit the cage. To insure plentiful supply of adults, needles containing mature larvae and pupae were collected from adjacent trees naturally infested and placed about the bases of the caged trees. As was the case with similar material taken to the field station, the incidence of parasitism ran so high that few adults emerged, and additional material had to be secured from Forsyth Basin (July 23).

Eight of the trees were used for control tests and the remaining four for life history observations and checks for the sprayed trees. Additional treatments were to have been applied to nearby trees naturally infested, but the great reduction in needleminer population made itnecessary to carry these tests out at Forsyth Basin.

Forsyth Basin and Pass. (Elevation 9000 and 9200 feet)

Some collections and observations were made at the pass (Fig. 1, -4) but most of the activities including the spray tests were carried out further south (Fig. 1, -5). The trees treated for control were slightly larger than those at Porcupine Flat, ranging from 10 to 15 feet in height; a total of 35 trees were under observation, thirty of which were sprayed and five designated as checks.

LIFE HISTORY STUDIES

This species of needleminer has a two year life cycle, the adults appearing in the odd numbered years, 1933, 1935, 1937, etc. As described by Patterson (3) the adults emerge from the first part of July to the latter part of August and eggs are deposited from the end of July to early September. New larvae appear during August and into the first week in September. Upon hatching, they go into needles on new growth and feed until cold weather stops activity. Feeding is resumed in the spring and during the last half of the following August the larvae migrate to new needles where they spend the second winter. Early in the spring of the second year, a second migration to new needles takes place. The larvae pupate in this third set of needles from the first week in June to the first week in August. Flight of adults starts again in July two years from the previous one. From the information reported by Salman and Hensill (8) and results of the past season's work, it appears that there may be variations in the time of occurrence of the different events depending upon season and locality; these variations have an important bearing on control work and will be discussed below.

Eight-Mile

The infested needles gathered at Porcupine Flat on July 3 contained larvae and pupae in about equal numbers; no emergence had occurred. Under the warm conditions prevailing at the field station, emergence started on July 6, reached the peak July 11 and ended July 22. The infested needles collected from Forsyth Pass on July 16 contained brood almost entirely in the pupal stage and a very few moths had emerged. In the second lot, collected from Forsyth Basin July 23, about 25 percent of the moths had emerged. This makes the subsequent data on longevity, sex ratios and incidence of parasitism somewhat incomplete. Emergence continued at a rapid rate after the needles were placed in the cages; the peak was attained almost at once and by August 5 all the adults were dead.

When the cages were removed from the trees, August 5, a careful search was made for eggs which were tagged for further observation. The first larva was found on August 15; the greatest number appeared in about two weeks (August 24 to 27) and the last on September 3, by which time nearly all the larvae had made will defined mines in the needles. When the last examination was made on October 21, the new mines ranged from 8 to 12 mm in length and the larvae were still active.

Porcupine Flat

Records of emergence and flight at Porcupine Flat are quite incomplete because of the tremenduous reduction in population and because it was possible to make observations only at ten day or two week intervals except for the month of August when Dr. DeLeon was here.

Development evidently takes place quite early in the spring, for although there were still traces of snow when first examined, June 22, 56 percent of the larvae had pupated; that figure probably represents nearly the total number that did reach the pupal stage, the remainder being parasitized. Many of the larvae also were parasitized and the few adults that did emerge were all out by July 16.

The material from Forsyth Basin was emerging when placed in the cages on July 24; the greatest number of moths were present about August 1 and by August 7 the numbers had greatly reduced; on August 19 all the adults were dead. The first eggs were found July 28; there is no way of knowing whether these were deposited by females emerging from the first needles placed in the cage July 3 or from that brought in July 24. Oviposition continued until August 6, after which no new eggs could be found even though a few adults remained in the cages.

No new larvae appeared until August 25; what were thought to be empty shells were seen several days earlier, but may have been infertile eggs which were drying. By September 2, new larvae were becoming more numerous, but many eggs were still unhatched on September 13. No further examination was made until October 1 and all had hatched by then. When last examined, October 20, the larvae were still actively feeding and had mined out 4 to 12 mm of the needles.

Forsyth Pass and Basin

As stated above, when the first collections were made on July 16, practically all the brood was in the pupal stage, emergence having just started. A week later, July 23, adults were quite numerous and when next examined, August 5, flight was at its peak. Only a few stragglers remained eleven days later, August 16, and by August 26 no adults could be found.

On August 5, eggs were found in twigs collected at the Pass but not in the twigs from the experimental plot; it is probable that eggs had been deposited throughout the area but were not present in the second sample. The period of oviposition ended some time between August 16 and 26.

No new larvae or mines could be found until a month later. On September 30 both mines and newly hatched larvae were found and it appeared that hatching had been going on for about a week. By October 19 all eggs had hatched and the new larval mines were about 6 mm in length.

Comparison with Other Reports

In general the time of occurrence of events in the 1937 season was, with some exceptions, the same as that reported by others (3, 8); a graphic comparison is given in Figure 2. The duration of the different steps was much shorter this year both in the caged and open trees and at lower and higher elevations. No explanation can be offered for this difference; it might possibly be a matter of temperatures from year to year, although a comparison of monthly mean temperatures taken at Yosemite Valley, the only complete records available, reveals no significant differences. Differences in temperature due to elevation are quite noticeable; each event occurred first At the Eight-Mile station (5500 feet) next at Porcupine Flat (7900 feet) and last at Forsyth Basin (9000)feet).

The most pronounced variation is in the time of hatching and the appearance of the new mines. In 1917 and 1919 at Lake Tenaya, the new larvae appeared 20 days earlier than at Porcupine Flat,in the 1935 season; on the other hand in the 1937 season, new larvae were found at Porcupine Flat some eleven days earlier than in the 1935 season. These irregularities are in each case greater than the variation in the flight periods and no explanation is offered. If more were known of the developmental threshold and complete temperature records were available, it might be that some answer could be found. In formulating a control program such variations must be kept constantly in mind; the correct date for treating in a given locality this year does not mean that the same date should be considered correct for all localities or even the same locality in another year.

NOTES ON HABITS AND DEVELOPMENT

These notes include only new information secured during the past season; observations reported previously are not included except for discussion.

Adults

When observed in the laboratory, the adults were found to be definitely attracted to light and were inactive in darkness. In the open and in field cages, however, activity was affected by temperatures and possibly by light intensity. At Eight-Mile the moths moved about the cages actively during the periods of dawn and dusk, but from about 10:00 A.M. to 5:00 P.M. they hung motionless on the tops of the cages and on the trees. At Porcupine Flat, because of the cool nights there would be little movement in the morning until the sunlight reached the cages; during the hottest part of the day activity would again cease and would be resumed from the middle of the afternoon until sundown or dusk, depending upon temperature. The moths at Forsyth Basin seemed to be active during the entire period of sunlight but became inactive at dusk. Any appreciable wind at any time of the day would inhibit activity, the moths hiding away in the foliage.

Because of limited time, sex ratios were determined by making sample counts at frequent intervals rather than attempting to keep a complete record for the entire period of emergence. It was found that the first moths were predominantly males, but as emergence progressed the proportion of females increased; for the entire population the number of males and females is approximately equal. The earlier emergence of the males may be a provision to assure fertilization of the females as soon as the latter are in flight; this presupposes that the males can copulate more than once, which may or may not be true.

Mating and oviposition were not observed, although the cages at Eight-Mile were watched at different periods of day and night during the time the adults were in flight. Several newly emerged adults were dissected; in every case the ovarioles of the females contained well formed eggs and the seminal vesicles of the males were filled with semen indicating that mating takes place soon after emergence; oviposition probably follows at once. Further examination revealed that each female has a potential total of about forty eggs; probably the total is seldom deposited for dead females taken from the cages after the flight period still contained from 9 to 38 eggs.

Nothing is known of the feeding habits of the adults, but it is possible that no food is taken during adult life, for in all the moths dissected the mouth parts and digestive tract appeared to be in a nonfunctional form. If this is the case, the energy requirement must be met by the fat body; this tissue is well developed in the female and although less so in the male, probably suffices for the shorter life span.

The length of life under conditions at the field station was from 3 to 15 days for the females and 3 to 5 days for the males. This is shorter than that previously reported, 14 to 16 days, and may have been reduced by the higher temperature prevailing and confinement in the small

cages, although in the larger cages at Porcupine Flat and in the natural infestation at Forsyth Basin the period was about the same. It is interesting to note that the males were much shorter lived than the females.

Eggs.

The eggs are usually deposited in a protected place along the stem. In 1919 nearly all were found under the scales at the base of the new needles. In the past season the greater portion were found behind the scales on the nodes between the current and year old growth, and between year old and two year old growth. Others were found in various places; some were under the fascicle scales on the lower of the new needles, some were similarly located on year old and two year old needles and a few even were found between the bases of a pair of needles. Nearly all were placed singly or in groups up to three or four although as many as fifteen were found in one group on a caged tree. They were usually oriented so that the head developed in the end which was outward or toward the apex of the twig. There was no cement-like substance covering the eggs; they were held only loosely by being forced down into place.

As the egg develops, the color gradually goes to a darker orange. After about twenty days the head starts to darken, and a few days later the fully formed segments can be seen. The larva then fills nearly all the space within the chorion; it is curved against the inner surface in the form of an oval so that the head and the posterior end overlap. If, at this time, the surface of the shell is lightly touched the larva will become quite active and may even make a complete revolution within the chorion. Hatching takes place 5 to 10 days after the larva becomes fully segmented. This makes the incubation period 30 to 40 days, which is over twice that reported by Patterson; it is possible that the difference may be due to variation in environmental conditions, particularly temperature.

The prolonged incubation period at Forsyth Basin, about 40 days, may explain why needleminer infestations have seldom been found above 9000 feet. It is not that the adults do not fly into the higher altitudes, for they were collected well above 9000 feet, but it may be that in the higher elevations the eggs cannot hatch in time for the larvae to become established in the needles before cold weather sets in.

Small Larvae.

The newly hatched larva has the same appearance as the mature larva except for size; the length is from 1.0 to 1.2 mm. and the color is light to deep orange.

No larvae were found in the act of escaping from the egg; however, from examination of empty shells and newly hatched larvae it appears that the shell is opened at the end by using the mouth parts and exerting pressure; no hatching spine or analogous structure could

be found on the larvae. Most of the larvae seemed to hatch during the morning hours.

Immediately upon leaving the shell the larva would wander about from one needle tip to another in search of a suitable place to start an entrance hole. After about 30 minutes to an hour a spot would be selected, almost invariably on the outer convex surface of the needle and about 5 mm. from the tip. First a thin matting of webbing would be spun below the spot and then the entrance hole was started. The first bites, the cuticle, were not ingested but were dropped over the side of the needle. This habit must be borne in mind in considering the efficiency of stomach poisons for control. The time required to enter the needles varied from 8 to 36 hours. The convex surface was probably preferred because the larva could secure a better "footing"; the mat of webbing also served as an additional aid.

During periods of high wind these migrating larvae crawled to the protected side of the needle and remained inactive. Some were blown from the needles but they usually remained attached by a thread and were able to return. No larvae were found to be suspended on threads more than 18 inches long so it is doubtful if there is any transfer from tree to tree by this means. If the wind did not abate within a few days and the temperature remained moderately warm, many larvae died. This, at times, might be a factor in reducing populations.

Of the many larvae and mines observed, only twice were two larvae found in the same needle and in both cases the two had started the entrance holes at approximately the same time. All four larvae died shortly after entering the needles.

After entering the needles the larvae continue feeding until cold weather stops activity. At the field station and at Porcupine Flat, most of the larvae first mined toward the apex of the needle and after cleaning out that portion, extended the mines downward; some larvae removed all the sub-cuticular tissue as they went, but others made only long narrow galleries just large enough to accomodate the larvae. At Forsyth Basin, however, nearly all the mines were directed downward instead of first going to the tip of the needle, and practically all were the elongate narrow type. When last examined, October 18 to 20, the larvae were still feeding and had developed mines as follows:

Eight-Mile Station	-	10 mm
Porcupine Flat	-	8 mm
Forsyth Basin	-	6 mm

PARASITES

When it was discovered that the needleminer brood at Porcupine Flat had been so heavily parasitized, special effort was made to determine which species were present and the importance of each. Needles containing larvae and pupae of the needleminer from Porcupine Flat and Forsyth Basin were placed in rearing cages and counts made on the numbers of moths and

parasites emerging each day. During the fall a temporary assistant separated the parasites collected into groups of species insofar as he was able, and representatives of each were sent to Washington for determination. Very little can be done in working up the data on the parasites until the determinations are received from the specialist, but a few observations will be presented.

The most numerous parasites were two Ichneumonids and a Chalcid; one of the former seemed to be a parasite of the pupal stage while the other Ichneumonid and the Chalcid were found only in larvae. In comparing ratio of parasites emerging to adults we find that at Porcupine Flat there were 3.3 to 1 and at Forsyth Basin 1.1 to 1. This, of course, does not mean that every parasite was responsible for the death of one needleminer for in some species several adults emerged from a single host. However, this is quite a contrast to incidence occurring in 1919 when only 12 percent of larvae were parasitized. The high ratio for the Porcupine Flat infestation, most probably was the principal factor in reducing the population from a highly epidemic state in 1935 to one approaching eradication in 1937. The work of parasites may also have been the cause of sudden disappearance in past years of similar infestations in the Tuolumne watershed.

CONTROL EXPERIMENTS

For the 1937 season the immediate objectives toward which the control work was directed were (1) to observe the effect of various formulae on lodgepole pine foliage, (2) to determine which formulae have the most effective ovicidal and larvicidal properties, and (3) to evolve some "rule of thumb" for timing the application of control measures.

All water sprays were applied with a small bucket pump having two 3 foot sectional extension rods and a Bordeaux nozzle. The vaporized oils were atomized from a modified fly sprayer attached to a Banner pressure pump.

The formulae used and preliminary results are given in the appendix. Final counts will not be made until next season, but at present the most effective combinations for the eggs and newly hatched larvae are as follows:

1. Fast breaking oil emulsions with nicotine sulphate or thiocyanates.
2. Inverted lead arsenate suspensions (Dynamite spreader) with nicotine sulphate.
3. Atomized oils with nicotine (alkaloid form) and possibly with lead arsenate.

Extensive use of lead arsenate or other stomach poison in a recreational area may be considered objectionable; however, the large quantity of foliage that would have to be ingested to produce toxic effects would

make the danger to humans or wild life very slight. The greatest cause of complaint would be the unnatural grey cast imparted to the sprayed foliage.

Careful watching of development has led to the conclusion that the spray should be applied a week to ten days after most of the eggs have reached the "black head" stage. In this way, the spray deposit will be subjected to a minimum of weathering during the period needed and thereby have a greater chance to kill any larvae which were not reached in the egg stage.

Examinations were made of the plots sprayed in 1935; the foliage injury which appeared in the spring of 1936 had entirely disappeared and the trees were in excellent condition. The needleminer has practically disappeared from the Porcupine Creek drainage. Some of the trees sprayed by Salman in the fall of 1936 showed considerable burning in the spring (table 5) but be the end of the season, the injured needles had dropped and the trees were well on the way to recovery. It seems, therefore, that although oil sprays may give a stand an unsightly appearance the following spring, the injury is much less than that caused by heavy needleminer defoliation and under normal conditions is of very short duration.

OTHER SPECIES OF NEEDLEMINER

From time to time needleminer activities on other host species have been reported, but practically no study has been made to determine the species involwed or their life histories.

Two collections and rearings were made during the past season. On June 22, Assistant Forester Ernst and the writer collected some mined needles from western white pine at the Snow Flat Summit. These larvae web three or four needles together and work within the protected bundle. Several bundles of infested needles were collected for rearing (Hopkins No. 32003) but only hymenopterous parasites emerged. The present population is so small that no damage is being done. G. R. Struble, on July 6, collected mined needles containing larvae and pupae from white fir in Mariposa Grove (Hopkins No. 32004). The larvae are very similar in appearance to those of R. milleri, but the pupae are light brown instead of black and the adults which later emerged are quite differently marked. Nothing is known of habits or life history of either species. Specimens of the latter have been sent to Washington for determination. Time did not permit collecting and rearing of the needleminer attacking Jeffrey pine in the Merced Lake area.

SUGGESTIONS FOR FUTURE INVESTIGATIONS

There are still many points in the biology that need checking and in 1938 and 1939 it is hoped that more information can be obtained;

fall and spring migrations, oviposition, and period of incubation particularly should be studied. A more thorough study of parasites would also be of first importance, and on this point it would be well to conduct a supplementary investigation of the infestation at Mineral King where natural forces have held the population in check for many years. Incidental collections and rearings of other needleminer species should be continued.

No additional control work can be done on eggs and small larvae until 1939 and at that time we will have the complete results on this season's work for a guide. In the meantime it would be desirable to apply some tests for control of the migrating larvae in the fall of 1938 for it is entirely possible that development of an effective treatment for the non-flight years might be of considerable aid in controlling epidemic outbreaks.

SUMMARY

The work of the past season was directed toward gaining additional information on the biology of the needleminer, and toward development of more effective methods of control. The following are the more important points brought out:

A. Biological phases.
   1. The potential number of offspring from any one female is thirty or more.
   2. Eggs may be deposited near both old or new growth.
   3. The incubation period may vary from 14 to more than 30 days, depending upon locality and season.
   4. The larvae spend a week to ten days or more within the shells after becoming fully segmented. This habit serves as a key to timing spray applications.
   5. Newly hatched larvae spend a short time wandering from needle to needle before starting a mine. This exposes the larvae to any spray deposit present for a longer period than would occur if they entered the nearest needle immediately upon leaving the shell.
   6. Periods of high wind or low temperature greatly impede the newly hatched larvae and may be a factor in limiting distribution in the higher altitudes.
   7. Parasites may at times become sufficiently numerous to effectively control an epidemic infestation.

B. Control experiments.
   1. The best way to determine the date to apply sprays is to watch the development of the eggs. The most effective time is a week to ten days after most of the eggs have reached the "black head" stage.

2. The most effective combinations for control of eggs and newly hatched larvae are as follows:

(a) Fast breaking oil emulsions with nicotine sulphate or organic thiocyanates.

(b) Inverted lead arsenate suspensions with nicotine sulphate.

(c) Atomized oils with alkaloid nicotine and possibly with lead arsenate.

ACKNOWLEDGMENT

The writer wishes to express appreciation for the cooperation of Mr. G. R. Struble and Dr. Donald DeLeon; the former for his suggestions and assistance in getting the field work under way, and the latter for car carrying on observations at Porcupine Flat and Forsyth Basin. Thanks are also due Assistant Forester Emil Ernst of Yosemite National Park for kindness in arranging for the use of pack stock, help in collecting material and numerous other accomodations.

APPENDIX

Table I

Foliage Tolerance Test - Pot Hole, 1937.

The un-infested trees selected for the foliage tolerance tests were last examined September 28 and the results are given below:

Tree No.	Formula	Wetting	Foliage Injury
S 1	Lethane 440, 1:200	Poor	None
S 2	Same as 1	Poor	None
S 3	Lethane 440, 1:400	Poor	None
S 4	Lethane 440, 1:400 & blood albumen, 4 oz.	Fair	None
S 5	Lethane 440, 1:600 Light medium oil, 1% Blood albumen, 4 oz.	Fair	None
S 6	Same as 5	Fair	None
S 7	Light medium greenol, 4% "conditioner" (oleate) 2 lbs.	Good on old growth. Poor on new growth.	None
S 8	Selocide, 1:500 Wettable sulphur, 2 lbs	Poor	None
S 9	Lead arsenate, 3 lbs. Dynamite spreader,* ½ lb. Kerosene, 2 qts.	Only fair at start, but on breaking lays down a very heavy and uniform deposit.	None
S 10	Lead arsenate, 3 lbs. light medium oil, 1% Spra-On spreader, 5 oz.	Poor - light deposit.	None
S 11	Lead arsenate, 3 lbs. Light medium oil, 1% Orthex adhesive, 3 pints	Fair - only a light deposit on new growth.	None

* As used in this report is the commercial preparation of the spreader developed by Marshall and Groves (2).

Tree No.	Formula	Wetting	Foliage Injury
S 12	Light medium oil, 3% Ortho liquid spreader, ½ pint.	Very poor.	None
S 13	Lethane 440, 1:400 Light medium oil, 3% Blood albumen, 4 oz.	Fair but breaks out to cover well.	Severe burn on old growth.
S 14	Vapo dust standard atomized	Excellent	None
S 15	Vapodust heavy atomized	Excellent	Slight
S 16	Vapodust A (light) atomized	Excellent	None
S 17	Vapodust B (heavy) atomized	Excellent	None
S 18	Vapodust C (medium) atomized	Excellent	None
S 19	Dinitro** 0.03% Light medium oil, 2% Blood albumen, 4 oz per 100 gal.	Fair	Slight - old growth
S 20	Dinitro, 0.01% Light medium oil, 1.0%. Blood albumen, 4 oz per 100 gal	Fair	Slight - old growth
S 21	Vapodust heavh, 50% Standard lead arsenate, 75 lbs. per 100 gal. 97% nicotine, 1%. Water to make volume. Atomized.	Irregular deposit	Very slight
S 22	Vapodust heavy, 50% Dinitro (powder), 1% Water to make volume, atomized	Excellent	Moderate

** As used in this report refers to dinitro-ortho-cyclo-hexyl-phenol. In all water sprays of this compound, preparation was by the method of Kagy and Richardson (1).

Table 2

Control Tests - Forsyth Basin, 1937

These trees were sprayed on August 12 to 14. This was considerably earlier than desired for a few moths were still in flight and none of the eggs had developed even to the "black head" stage, but since pack stock to transport materials into the area might not have been available at a later date, it was preferable to apply the tests early rather than risk losing out altogether. All formulae were applied in duplicate.

Tree No.	Formula	Wetting	Foliage Injury	Control
1	Dinitro, 0.01%. Light medium oil 1.0% Blood albumen, 4 oz.	Fair	Light	None
2	Same as 1.	Fair	Light	None
3	Dinitro, 0.03% Light medium oil, 3.0% Blood albumen, 4 oz	Fair	Severe	Excellent
4	Same as 3	Fair	Moderate	Good
5	Light medium greenol, 4% Ortho-nicotine, 5 lbs. Conditioner (oleate) 2 lbs	Good on old growth. Poor on new growth Good on scales.	None	Fair
6	Same as 5	Same as 5	None	Good
7	Phenothiazine, 3 lbs.	Fair	None	Poor
8	Same as 7	Fair	None	None
9	Lethane 440, 1:400 Light medium oil, 4% Blood albumen, 4 oz	Breaks to cover well	Light	Fair
10	Same as 9	Breaks to cover well	Moderate	Excellent
11	Japanese beetle repellent* 4 lbs.	Irregular	None	None
12	Same as 11.	Irregular	None	Poor

* Tetramethyl-thiuram-disulphide.

Tree No.	Formula	Wetting	Foliage Injury	Control
13	Lead arsenate, 4 lbs Dynamite spreader, ½ lb. Kerosene, 2 qts. Nicotine sulphate,40%, 1 pt	Excellent deposit	None	Excellent
14	Same as 13	Excellent deposit	None	Excellent
16	Lead arsenate, 4 lbs. Light medium oil, 4% Nicotine sulphate 40%, 1pt. Blood albumen, 4 oz	Good, but deposit light	None	Excellent
17	Same as 16	Light deposit - even	None	Excellent
18	Light medium oil, 4% Nicotine sulphate 40%, 1 pt. Blood albumen, 4 oz	Breaks to cover well	Light	Excellent
19	Same as 18	Breaks to cover well	Light	Excellent
20	Dinitro, 1% Vapodust heavy, 50% Water to make volume atomized	Irregular - small nozzle	Light	None
21	Same as 20	Fair - Large nozzle	Moderate to heavy	None
22	Lead arsenate, 75 lbs. 95% nicotine, 1% Vapodust heavy, 50% Water to make volume atomized	Light to heavy deposit	None	Excellent
23	Same as 22	Irregular	None	Excellent
24	Vapodust heavy, 99% 95% nicotine 1% Atomized	Excellent but tends to be irregular	Light	Excellent
25	Same as 24	Same as 24	Moderate	Good

Tree No.	Formula	Wetting	Foliage Injury	Control
26	Vapo dust A (light), 99% Nicotine 95%, 1% Atomized	Same as 24	Light	Excellent
27	Same as 26	Same as 24	None	Good
28	Vapodust B (heavy), 99% Nicotine 95%, 1% Atomized	Same as 24	Light	Excellent
29	Same as 28	Same as 24	Moderate	Poor
30	Vapodust C (medium) 99% Nicotine 95%, 1% Atomized	Same as 24	None	Fair
35	Same as 30	Same as 24	None	Fair

Check trees Nos. 15, 31, 32, 33, 34.

Table 3.

Control Tests - Eight-Mile, 1937.

The spraying of the small caged trees was timed just as desired; the first larva was found August 15, and treatment was applied the next day. The value of the comparisons given in the following table are open to question because the infestation varied so greatly from tree to tree.

Table 3

Tree No.	Formula	Wetting	Foliage Injury	Control
6	Dinitro, 0.03% Light medium oil, 3% Blood albumen, 4 oz.	Fair	Moderate	Good
7	Dinitro, 0.01% Light medium oil, 1.0% Blood albumen, 4 oz	Fair	Light	Good
8	Light medium greenol, 4% Ortho nicotine, 5 lbs Conditioner (oleate) 2 lbs	Fair	None	Poor
9	Phenothiazine, 3 lbs	Poor	None	Poor
10	Selacide, 1:500 Sulphur (wettable) 2 lbs	Poor	None	None
11	Lethane 440, 1:400 Light medium oil, 4% Blood albumen, 4 oz	Good	Light	Excellent
12	Lead arsenate, 4 lbs Dynamite spreader, ½ lb Kerosene, 2 qts Nicotine sulphate 40%, 1pt	Excellent - heavy deposit	None	Fair
13	Dinitro, 1% Vapodust heavy, 50% Water to make volume Atomized	Excellent	Very severe defoliation	Good
14	Vapodust heavy, 99% Nicotine 95%, 1% Atomized	Excellent	Light	Excellent
15	Lead arsenate, 75 lbs Nicotine 95%, 1% Vapodust heavy, 50% Water to make volume Atomized	Good	Light	Excellent

Check trees - Nos. 1 to 5.

Table 4

Control Tests - Porcupine Flat, 1937

The eight caged trees at Porcupine Flat were sprayed August 20, or about one week before the first eggs hatched; at that time we could not predict the time of hatching by observing the eggs so it was decided to err on the side of being a little early rather than late. Here again the results can not be considered more than indicative because of the irregularity of the infestation from tree to tree.

Tree No.	Foliage	Wetting	Foliage Injury	Control
124	Lead arsenate, 75 lbs Vapodust heavy, 50% Nicotine 95%, 1% Water to make vol. Atomized	Good	None	None
125	Vapodust heavy, 99% Nicotine 95%, 1% . Atomized	Irregular	None	Fair
126	Dinitro, 1% Vapodust heavy, 50% Water to make vol. Atomized	Good	Severe	None
127	Lethane 440, 1:400 Light medium oil, 4% Blood albumen, 4 oz	Breaks to cover well	Light	Poor
128	Light medium oil, 4% Nicotine sulphate 40%, 1 pt Blood albumen, 4 oz	Breaks to cover well	None Excellent	Excellent
131	Dinitro, 0.03% Light medium oil, 3.0% Blood albumen, 4 oz	Fair	Moderate	Poor
132	Dinitro, 0.01% Light medium oil, 1.0% Blood albumen, 4 oz	Fair	Moderate	None
139	Light medium greenol, 4% Ortho nicotine, 5 lbs Conditioner (oleate) 2 lbs	Fair to good	None	Good

Check trees - Nos. 123, 129, 133.

Table 5

Foliage Tolerance - Porcupine Flat, 1936

In the fall of 1936, Salman applied several test sprays at Porcupine Flat and the writer kept these trees under observation during the past season.

Tree No.	Formula	Foliage Injury
108	Lethane 440, 2%	None
109	Kerosene, 1% Blood albumen, 4 oz	None
110	Kerosene, 2% Blood albumen, 4 oz	None
111	Kerosene, 4% Blood albumen, 4 oz	None
112	Kerosene, 8% Blood albumen, 4 oz	None
113	Shell tank mix oil #2, 2% Blood albumen, 4 oz	None
114	Shell tank mix oil #2, 4% Blood albumen, 4 oz	None
115	Shell tank mix oil #2, 8% Blood albumen, 4 oz	Severe burn above 4 feet
116	Shell tank mix oil #3, 4% Blood albumen, 4 oz	None
117	Shell tank mix oil #3, 8% Blood albumen, 4 oz	None
118	Ortho spray oil #5, 4% Blood albumen, 4 oz	Irregular burn above 5 feet
119	Shell tank mix oil #10, 4% Blood albumen, 4 oz	Irregular burn above 5 feet
120	Shell tank mix oil #10, 8% Blood albumen, 4 oz	Severe burn above 4 feet

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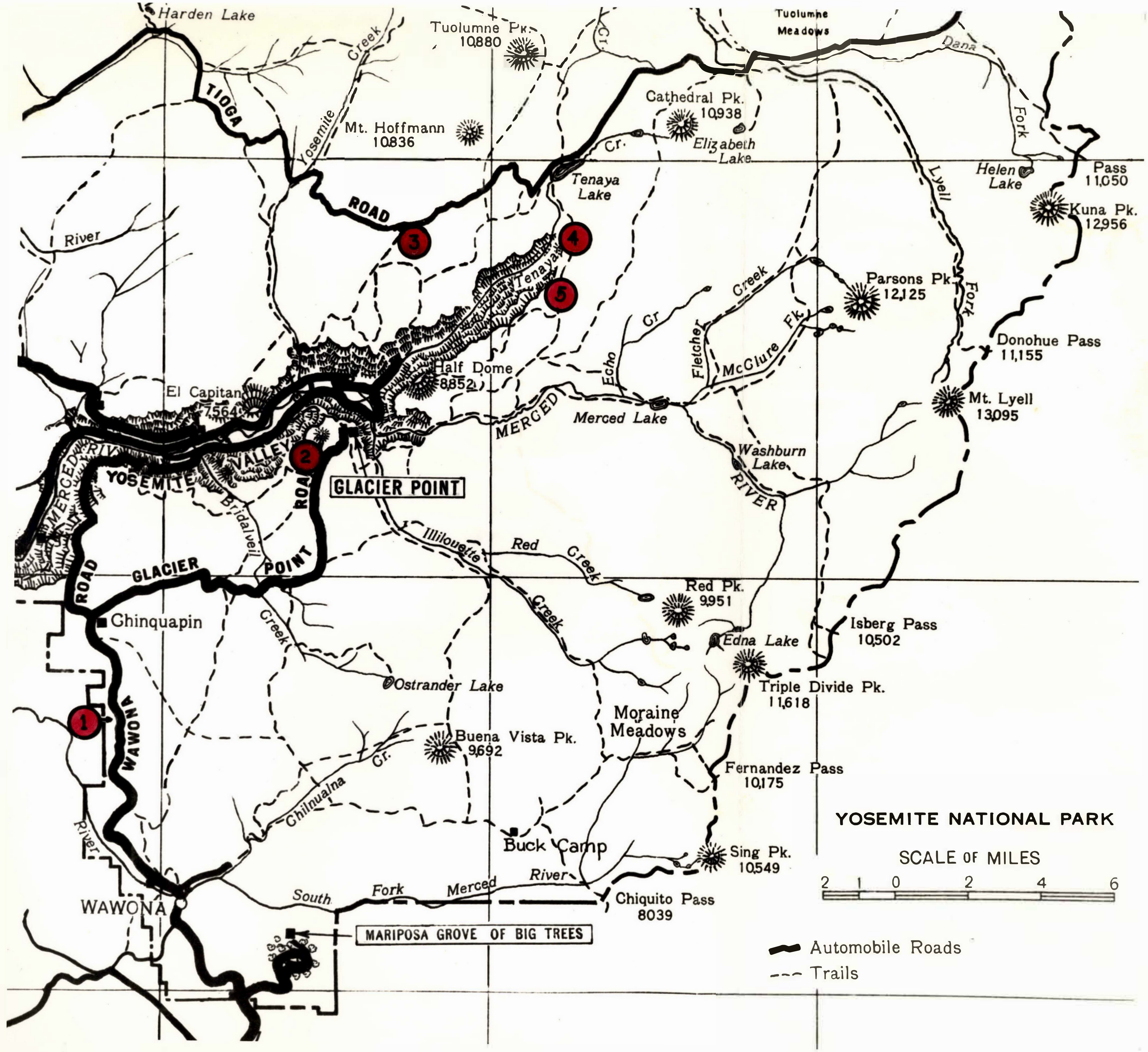

YOSEMITE NATIONAL PARK
SCALE OF MILES
2 1 0 2 4 6
Automobile Roads
Trails
Harden Lake
Tuolumne Pk.
10,880
Tuolumne Meadows
Dana
TIOGA
ROAD
Mt. Hoffmann
10,836
Cathedral Pk.
10,938
Elizabeth Lake
Tenaya Lake
Helen Lake
Pass
11,050
Kuna Pk.
12,956
Parsons Pk.
12,125
Donohue Pass
11,155
Mt. Lyell
13,095
Half Dome
8,852
El Capitan
7,564
Merced Lake
Washburn Lake
MERCED
RIVER
McClure Fk.
Fletcher
Echo
YOSEMITE
VALLEY
GLACIER POINT
GLACIER
POINT
ROAD
Bridalveil
Illilouette
Red
Creek
Red Pk.
9,951
Edna Lake
Isberg Pass
10,502
Triple Divide Pk.
11,618
Chinquapin
Ostrander Lake
Moraine Meadows
Buena Vista Pk.
9,692
WAWONA
Fernandez Pass
10,175
Chilnualna
Buck Camp
Sing Pk.
10,549
South Fork Merced River
Chiquito Pass
8039
MARIPOSA GROVE OF BIG TREES
1
2
3
4
5

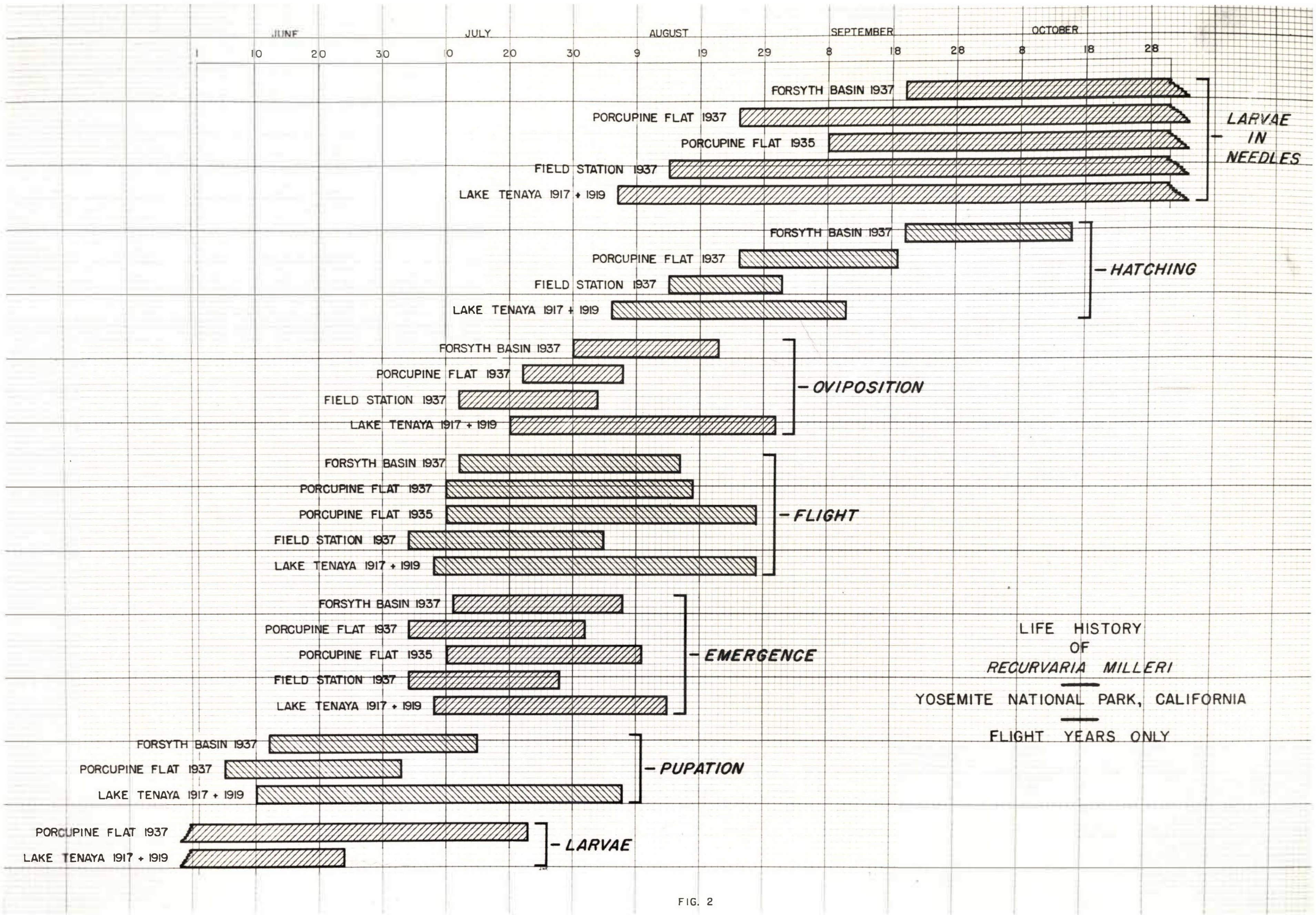
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
1 10 20 30 10 20 30 9 19 29 8 18 28 8 18 28
FORSYTH BASIN 1937
PORCUPINE FLAT 1937
PORCUPINE FLAT 1935
FIELD STATION 1937
LAKE TENAYA 1917 + 1919
LARVAE IN NEEDLES
FORSYTH BASIN 1937
PORCUPINE FLAT 1937
FIELD STATION 1937
LAKE TENAYA 1917 + 1919
HATCHING
FORSYTH BASIN 1937
PORCUPINE FLAT 1937
FIELD STATION 1937
LAKE TENAYA 1917 + 1919
OVIPOSITION
FORSYTH BASIN 1937
PORCUPINE FLAT 1937
PORCUPINE FLAT 1935
FIELD STATION 1937
LAKE TENAYA 1917 + 1919
FLIGHT
FORSYTH BASIN 1937
PORCUPINE FLAT 1937
PORCUPINE FLAT 1935
FIELD STATION 1937
LAKE TENAYA 1917 + 1919
EMERGENCE
FORSYTH BASIN 1937
PORCUPINE FLAT 1937
LAKE TENAYA 1917 + 1919
PUPATION
PORCUPINE FLAT 1937
LAKE TENAYA 1917 + 1919
LARVAE
LIFE HISTORY
OF
RECURVARIA MILLERI
YOSEMITE NATIONAL PARK, CALIFORNIA
FLIGHT YEARS ONLY

FIG. 2

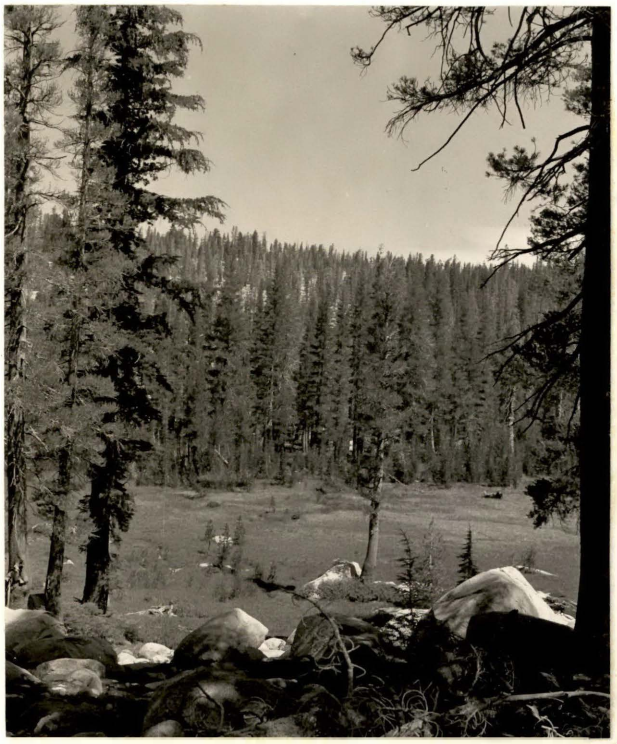

Figure 3.

Heavy needleminer infestation in Forsyth Basin, looking toward the pass. (Panchromatic film with red filter) No. 9960A.

Figure 4

Heavily infested lodgepole pine trees in Forsyth Basin near the experimental plot. Note dead and dying tops. (Panchromatic film and red filter) No. 9960C.

Figure 5

Ghost forest near Lake Tenaya caused by needleminer defoliation followed by mountain pine beetle attacks. Photo by J. M. Miller. No. 2191

Figure 6

Heavily infested tip (left) and normal tip (right). (Panchromatic film and red filter). No. 9958.

Figure 7

Needles containing pupa and mature larva. Photo by J.E. Patterson. No. 5652.

Figure 8

Entrance holes and mines of small larvae. Photo by K.A. Salman. No. 757D.

Figure 9

Boxed tree used for life history and control studies at the field station. No. 9959A.

Figure 10

Boxed tree enclosed in muslin cage. No. 9959B.

Figure 11

Rack of caged trees at the field station. No. 9959C.

Figure 12

Large cage used at the field station to determine effect of greater flight space on infestation. Photo by G. R. Struble. No. 9940.

Figure 13

Small trees at field station set in pit and protected by wire netting for winter storage. No. 9959D.

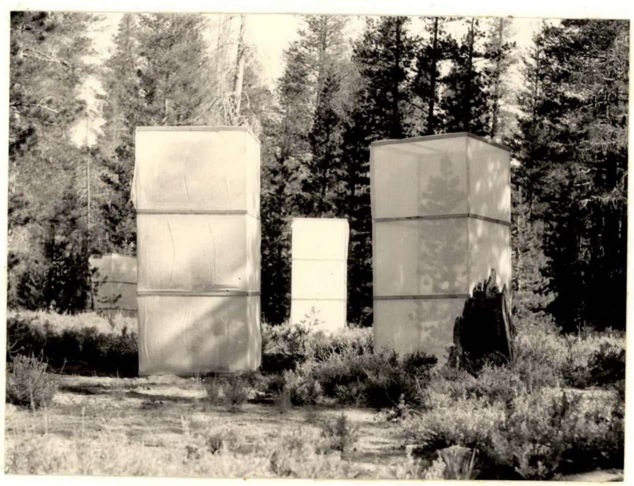

Figure 14

Caged trees at Porcupine Flat. No. 9959E.